XX. *On the Electric Conducting Power of the Metals. By* AUGUSTUS MATTHIESSEN, *Ph.D. Communicated by* CHARLES WHEATSTONE, *Esq.*, *F.R.S.*

Received November 20, 1857,—Read January 14, 1858.

REQUIRING for my research on thermo-electricity a great many metals, which were for the most part chemically pure, I thought it would be interesting to determine at the same time their electric conducting power. The method used for these determinations was the same as that described in the Philosophical Magazine (February 1857), and the experiments were made in the Heidelberg Physical Laboratory under the direction of Professor KIRCHHOFF.

The values given in the following series are the results obtained with different wires of the same metal compared with silver, 100 at 0°.

	Conducting power.	Temperature. °C.	Mean of conducting power.	Temperature. °C.
Silver	100	at 0	100	0
Copper, No. 3	77·43	at 18·8	77·43	18·8
Copper, No. 2	72·70	at 22·6	72·06	22·6
	71·43	at 22·6		
Gold	55·16	at 21·6	55·19	21·8
	55·24	at 21·8		
	55·17	at 22·0		
Sodium			37·43	21·7
Aluminium	33·44	at 19·2	33·76	19·6
	33·75	at 19·4		
	34·09	at 20·0		
Copper, No. 1	30·36	at 24·0	30·63	24·2
	30·70	at 24·0		
	30·55	at 24·2		
	30·90	at 24·5		
Zinc	27·41	at 17·4	27·39	17·6
	27·42	at 17·6		
	27·34	at 17·8		
Magnesium			25·47	17·0
Calcium			22·14	16·8
Cadmium	22·05	at 18·8	22·10	18·8
	22·09	at 18·8		
	22·16	at 18·8		

	Conducting power.	Temperature. °C.	Mean of conducting power.	Temperature. °C.
Potassium			20·85	20·4
Lithium			19·00	20·0
Iron	14·64	at 21·2	14·44	20·4
	14·46	at 21·2		
	14·68	at 19·0		
	14·33	at 19·0		
	14·10	at 21·4		
Palladium	12·60	at 17·0	12·64	17·2
	12·63	at 17·2		
	12·69	at 17·4		
Tin	11·39	at 21·0	11·45	21·0
	11·40	at 21·0		
	11·56	at 21·0		
Platinum	10·55	at 20·4	10·53	20·7
	10·46	at 20·8		
	10·57	at 21·0		
Lead	7·84	at 17·2	7·77	17·3
	7·73	at 17·2		
	7·74	at 17·4		
Argentine	7·73	at 20·0	7·67	18·7
	7·62	at 17·4		
	7·67	at 18·8		
Strontium			6·71	20·0
Antimony	4·28	at 18·7	4·29	18·7
	4·30	at 18·7		
	4·29	at 18·7		
Quicksilver	1·64	at 22·8	1·63	22·8
	1·63	at 22·8		
	1·62	at 22·8		
Bismuth	1·18	at 14·5	1·19	13·8
	1·19	at 14·8		
	1·21	at 12·0		
	1·19	at 14·0		
Alloy of	0·880	at 24·0	0·884	24·0
Bismuth 32 parts	0·883	at 24·0		
Antimony 1 part	0·889	at 24·0		
Alloy of	0·516	at 22·0	0·519	22·0
Bismuth 12 parts	0·536	at 22·0		
Tin 1 part	0·505	at 22·0		

	Conducting power.	Temperature. °C.	Mean of conducting power.	Temperature. °C.
Alloy of Antimony 2 parts Zinc 1 part	0·412 0·414	at 25·0 at 25·0	0·413	25·0
Graphite, No. 1	0·0719 0·0667	at 22·0 at 22·0	0·0693	22·0
Graphite, No. 2	0·0436 0·0436	at 22·0 at 22·0	0·0436	22·0
Gas-coke	0·0372 0·0405 0·0383	at 25·0 at 25·0 at 25·0	0·0386	25·0
Graphite, No. 3	0·00370 0·00420	at 22·0 at 22·0	0·00395	22·0
Bunsen's battery-coke	0·00217 0·00289 0·00233	at 26·2 at 26·2 at 26·2	0·00246	26·2
Tellurium	0·000742 0·000795 0·000794	at 20·0 at 20·0 at 18·7	0·000777	19·6
Red phosphorus	0·00000118 0·00000128	at 20·0 at 20·0	0·00000123	20·0

For the determination of the conducting powers of these bodies, whose electric resistance was very great, a number of normal wires of different lengths were made, and by these means accurate results were obtained.

The conducting powers of potassium and sodium* are here given to make the series complete. The alloys of bismuth-tin, bismuth-antimony, and antimony-zinc were determined in order to ascertain whether, as they give with other metals such strong thermo-electric currents, they might be more advantageously employed for thermo-electric batteries than those constructed of bismuth and antimony.

All the metals were the same as those used for my thermo-electric experiments, with the exception of cadmium, which was purified by my friend Mr. B. Jegel. Coppers Nos. 1, 2 and 3, were wires of commerce. In No. 1 small quantities of lead, tin, zinc, and nickel were found by Mr. Herschel, who was kind enough to analyse it. The small conducting powers of this sort may be attributed, according to the opinion of Professor Bunsen, to a trace of suboxide of copper probably contained in the same.

The values obtained for aluminium are nearly the same as those found by Poggendorff† and Buff‡.

Iron, Nos. 1, 2 and 3, were pianoforte wires. These determinations, although higher

* Phil. Mag. Feb. 1857. ‡ Pogg. Ann. vol. xcix. p. 643. ‡ Ann. Chim. Pharm. vol. cii. p 265.

than those found by nearly all of the earlier experimenters, are in accordance with the results lately made known by BUFF.

The wires of bismuth employed for these experiments were of a very small diameter (0·144 millim. and 0·185 millim.); for when manipulating with thicker ones, very varying results were obtained, probably owing to the disposition of the crystals, as MATTEUCCI* has already observed. In fact, twelve experiments made with such wires, when the conducting power varied from 1·11 to 1·36, gave as a mean 1·20, which agrees pretty accurately with the number in the above series.

Graphite No. 1 is the so-called pure Ceylon, No. 3 the purified German, and No. 2 a mixture of both, all used for making pencils. The specimens were purified by BRODIE'S patent, and pressed by Mr. CARTMELL, to whom I am indebted for the same. These, as well as the gas-coke and BUNSEN'S battery-coke, were shaped into thin rods by hand, and the ends coppered galvanoplastically.

To form the connexion in order to determine their conducting powers, one end stood in a cup of quicksilver, the other cup being formed by placing an india-rubber tubing over the other end, the latter cup being of course also filled with quicksilver. As the rods were made by hand, the difference in the results of the same specimens is thus accounted for.

An interesting fact was now observed, viz. that in all the cokes and graphites the conducting power increased by heat. Some experiments were made with gas-coke, and it was found that if at 0° the conducting power equalled 100, it, from 0° to 140°, increased 0·00245 for each degree, and between the common temperature and a light red heat, about 12 per cent.

For these experiments the connecting copper wires were soldered on to the coppered ends of the rods. The red phosphorus was likewise coppered galvanoplastically, and the values determined after the same method.

The following metals were chemically pure:—Silver, gold, zinc, cadmium, tin, lead, antimony, quicksilver, bismuth, tellurium; and the undermentioned pressed, viz. sodium, zinc, magnesium, calcium, cadmium, potassium, tin, lead, strontium, antimony, bismuth, alloy of bismuth-antimony, alloy of bismuth-tin, and tellurium.

No difficulty was found in pressing the above-mentioned wires, only with antimony and tellurium care must be taken in heating the press of the former to a dark red heat, and of the latter until it burns blue.

Quicksilver was determined in glass tubes, and the alloy of antimony-zinc cast likewise in small glass tubes, it being too hard to press and too brittle to draw. The remainder of the wires were drawn.

In conclusion, I will record a few experiments on the alloys of lead, tin, zinc and cadmium. The alloys made of two of these metals appear to conduct electricity after a very simple law; namely, their conducting power is the mean of the conducting power of the quantity of each metal employed, as the following results show.

* Comptes Rendus, vol. xl. p. 541.

	Mean of conducting power.	Mean of temperature. °C.	Calculated conducting power.
Sn Pb* . . .	9·20	21·4	9·09
Sn_4Pb . . .	10·55	22·0	10·31
Sn Pb_4 . . .	8·26	22·6	8·22
Zn Sn† . . .	17·43	22·0	17·13
Zn Cd ‡ . . .	23·78	20·8	24·04

The above values are the means of at least two agreeing results determined after the before-mentioned method, the metals being of course chemically pure.

With bismuth and antimony the same law does not appear to hold good; and how far with other metals this may be the case, I intend, as soon as I have procured a fresh supply of pure metals, to investigate and make known.

* If the equivalent of Sn =58·0 and Pb =103·7.

† If the equivalent of Zn =32·6.

‡ This alloy was prepared by Mr. B. JEGEL, who took the equivalent of Zn =32·53, and Cd =55·74.